Technical Memorandum

Summary of Groundwater Conditions at Triple Site

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To: Ms. Melanie Morash
U.S. Environmental Protection Agency
Task Order Project Officer

From: Aptim Federal Services, LLC

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The following status summary on Triple Site groundwater is based upon recent documents by Locus submitted on behalf of Philips (Signetics), AECOM for TRW, and Haley & Aldrich for AMD 901/902. These recent documents are supplemented by the Remedial Investigation Report from 1991, the Feasibility Study from 1991, and a few site specific reports for the three sites. However, little information was available prior to about 2005, except for the two1991 reports.

Triple Site is composed of source areas at Signetics, TRW, and AMD 0901/902 Sites and the downgradient combined groundwater plume referred to as the Offsite Operable Unit (OOU). Figures 1 through 4 are TCE isoconcentration maps as reported by Locus for the 2018 annual report that included data from Signetics, TRW, and both AMD sites. The AMD 915 Site appears to have contributed to the OOU groundwater plume but was not included in the 1991 Record of Decision for Triple Site. The vadose-zone source areas were identified at the three sites with TCE as the primary contaminant of concern. Although the site investigation found very elevated concentrations of TCE and other chlorinated ethenes, no DNAPL was found during removal and mitigation of the source areas at these sites. However, at the Signetics site DNAPL was found at a depth of 70 feet below grade in 1996. All source areas were addressed early on in the remedial effort by excavation and/or SVE and little residual source remains in the vadose zone. As the OOU is a down gradient groundwater plume it did not have any internal sources.

Groundwater extraction and treatment was the selected remedy for all four sites. Clean up time frames using a batch flush approach for each of the sites were; 18 years for AMD, 7 years for

TRW, 24 years for Signetics, and 36 years for the OOU. Each of these sites are addressed in the following sections.

AMD 901/902 Site

The AMD 901/902 groundwater extraction system was installed and began operations in 1984. The system targeted a relatively small area in the northwestern corner of the site. It initially consisted of extraction from the A and B1 aquifer zones and was augmented with extraction from the B2 aquifer zone in 1989. Additional extraction wells were subsequently installed into the aquifer zones to increase groundwater extraction and groundwater modeling was conducted to confirm plume capture. Asymptotic mass extraction was observed by 1995 indicating that removal efficiency was controlled by diffusion from low permeability units within the saturated zone. The groundwater extraction and treatment system was shut down in 2002 to evaluate in situ bioremediation (ISB) as an enhanced remedy. During its operation, the groundwater extraction and treatment system removed approximately 230 million gallons of groundwater containing approximately 660 pounds of contaminant. The initial average TCE concentration in A aquifer zone wells in 1982 was about 2,450 µg/L and that at shut down in 2002 TCE concentrations averaged about 194 µg/L. Similar with the B1 aquifer zone, the initial average TCE concentration was about 4,657 µg/L in 1982 and about 174 µg/L when the system was shut down in 2002.

To address the residual mass in low permeability unit, a pilot study applying ISB was completed in 2004. The pilot study extracted groundwater, removed the VOCs using granular activated carbon, conditioned the groundwater, added molasses, and reinjected the augmented groundwater upgradient of the treatment area. The pilot study resulted in a decreased of about 90 percent of the VOCs in groundwater in the treatment area. The CSM was updated to include channelized flow through high permeability units and residual contamination in low permeability units that was used as a bases for modeled comparison (MODFLOW and MT3DMS) of the ISB pilot test results and the previous groundwater extraction system. Modeling indicated that the ISB remediation time frame would be accelerated four fold as compared to the more passive groundwater extraction and treatment.

An expanded (full scale with new wells) system was implemented in 2005 with recirculation of extracted groundwater from downgradient of the treatment area (maintaining hydraulic capture of the contaminant plume), removal of VOCs using activated carbon, augmentation with molasses, and reinjection upgradient of the treatment area. Active operation of the system has been periodic, and reinjection were triggered by depletion of substrate present in groundwater. Molasses, potassium lactate, and sodium lactate have been used as a substrate. Currently injections occur about annually with a cumulative reinjection volume of about 364,000 gallons into the A aquifer zone and 628,000 gallons into the B aquifer zones. That

application of ISB has been successful, in 2018 the average A aquifer zone well TCE concentration had decreased to 31 µg/L from 194 µg/L prior to ISB and the average B1 aquifer zone well TCE concentration had decreased to 104 µg/L compared to 174 µg/L prior to ISB.

TRW Site

The TRW Site groundwater extraction and treatment system began operation in 1985 from the A, B1, and B2 aquifer zones. Groundwater modeling was conducted in 1988 to confirm capture and optimize the extraction system. TRW concluded in 1998 that decreases in dissolved mass removal (near asymptotic) indicated that the system had reach technical limitations. Groundwater extraction and treatment was suspended in 2001 to evaluate application of ISB. At the time of shut down, the system had removed approximately 115 million gallons of groundwater containing about 3,050 pounds of VOCs. Site redevelopment has resulted in the destruction of some initial remediation wells and the addition of others: however, continuously sampled A aquifer wells indicated an average TCE concentration prior to system activation was about 2,960 µg/L that compares to 107 µg/L at shutdown in 2001. Similarly, the average B1 aquifer zone TCE concentration prior to groundwater extraction and treatment was about 11,830 µg/L and at shutdown in 2001 the average had decreased to about 470 µg/L.

Numerous injections of substrate for enhancing ISB have occurred since 2000. Three injection events between 2000 and 2005 used hydrogen releasing compound. Cheese whey was applied in 2007 and 2008. Emulsified vegetable oil (EVO) and Anaerobic BioChem Plus were periodically injected from 2010 to 2014, and the injections were augmented with dehalococcides bacteria. Continuously sampled A aquifer zone wells indicated the current average TCE concentration is about 63 µg/L and that of the B1 aquifer zone wells is about 410 µg/L. A robust update to the CSM based upon Environmental Sequence Stratigraphy and the presence of Freon 113 documented that contaminant migration from upgradient sources at the AMD 901/902 and Signetics sites mitigates further reductions in TCE and associated contaminants beneath the TRW site.

Signetics Site

The Signetics groundwater extraction and treatment system began operations in 1982. It consists, or has consisted, of various extraction components that included three basement dewatering system, the 440 Wolf Road extraction trench, the 811 Arques extraction trench, and individual extraction wells in the A, B1, and B2 aquifer zones. Most components of the extraction and treatment system are still operational and a total of about 43,600 pounds of contaminants have been removed from the site. Currently, the 811 Arques extraction trench and ten A aquifer and one B1 aquifer extraction wells are shut down for treatability testing for

ISB. Insufficient information is available to detail mass removal from each of the remedial extraction components or total groundwater extracted.

The effectiveness of the groundwater extraction and treatment system is reflected in the average TCE concentrations in monitoring and extraction wells along the northern portion of the Signetics site. The average A aquifer zone concentration prior to activation of the wells (varies from 1982 to 1990) was about 2,700 µg/L and that found in 2018 from these wells averaged about 98 µg/L. Similarly, for the B1 aquifer zone, monitoring and extraction wells averaged about 5,170 µg/L prior to activation and about 660 µg/L in 2018.

A similar evaluation can be made for the effectiveness of the groundwater extraction and treatment system in the vicinity of the 811 extraction trench in the central portion of the site that was the area targeted for the ISB treatability study in 2016. Prior to activation of the system, the average TCE concentration in monitoring and extraction wells in the vicinity of the 811 extraction trench was about 21,380 µg/L and in 2016 the average was about 5,090 µg/L. In the B1 aquifer zone, the average initial TCE concentration of one extraction and two monitoring wells was about 25,000 µg/L that was reduced to about 4,670 µg/L in 2016.

The Signetics groundwater extraction and treatment system has reduced TCE concentrations appreciably, but elevated concentrations remain. In 2018, the system removed 34.6 million gallons of groundwater from beneath the site that contained 343 pounds of contaminants. Although mass extraction concentrations are reduced and approaching asymptotic, the mass being removed from groundwater and the requirement for prevention of offsite migration has precluded the termination of the system.

The ISB treatability study conducted in 2016 consisted of injection of EVO and a bioaugmentation culture at three locations and zero valent iron (ZVI) and guar at two locations. Application of ISB at the Signetics site is more complicated than at the other Triple Site sites as Freon 113 exists in appreciable concentrations, in fact the DNAPL observed in 1996 beneath the site was composed of 2/3 TCE and 1/3 Freon 113. Approximately 440 gallons of EVO, 63 gallons of ZVI, and 30 pounds of guar were used in the treatability study. Results of the testing suggested that reducing conditions were initiated and TCE did degrade; however, little degradation of c-DCE and Freon 113 were indicated. Additional testing is required to evaluate the application of ISB to the Signetics site.

Offsite Operable Unit

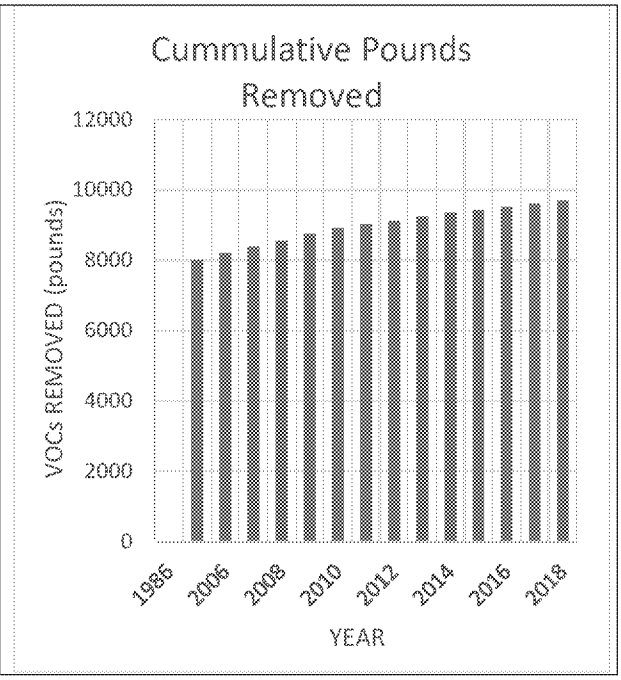
The OOU is the most critical of the four Triple Sites in that the vapor intrusion (VI) risk from TCE appears to be the greatest current threat to human health related to the Triple Site. The TCE plumes above regulatory level in the both the A and B aquifer zones extends more than 4,500 feet downgradient beneath four schools and over 500 residences. Of the more than 220

households and school buildings sampled for VI concerns, mitigation has proceeded on over 20 structures.

The OOU groundwater extraction and treatment system is composed of four extraction well clusters spaced from about 600 feet to 1200 feet apart along Duane, Carmel, Alvarado, and Ahwanee Avenues. The Duane Avenue extraction cluster was placed in operation in 1986 and consists of four A, one B1, one B2, two B3, and one B4 aquifer zone wells. The Carmel Avenue cluster consists of two B1, and two B2 aquifer zone wells. Well COM01A along Carmel Avenue is reported as an A aquifer extraction well, but there is no indication in the reported data that active extraction is occurring in this well. The Alvarado Avenue cluster consists of four A, four B1, and two B2 aquifer zone wells. The Ahwanee Avenue cluster consists of one A, two B1, and two B2 aquifer zone wells. The Duane Avenue extraction well cluster was activated in 1986 and the remaining three clusters were activated in 1988 and augmented with additional wells in 1992.

Operational effectiveness of the extraction and treatment system is difficult to evaluate as few data are available. It appears that 9,431 pounds of VOCs had been extracted and treated by the end of 2015 and subsequently an additional 273 pounds had been recovered by the end of 2018. No estimate of the total extracted and treated groundwater can be made. However, extraction and treatment since 2005 was reconstructed from individual reports and summarized below.

Date	Gallons (millions)	VOCs (pounds)
2005	66.2	194
2006	66	183
2007	61.6	157
2008	61.9	204
2009	53.5	161
2010	47.7	118
2011	47.7	96
2012	51.5	115
2013	51.7	113
2014	31.8	72
2015	41.4	95
2016	43.5	91
2017	41.7	87
2018	45.8	95



As can be seen in the Cumulative Pounds Removed graph, the mass extraction of the OOU system is approaching an asymptotic condition even through the system is extracting about

100 pounds of VOCs per year. Part of the asymptotic nature of the extracted mass is likely a result of the decrease in the groundwater extraction rate from 66 million gallons in 2005 to less than 46 million gallons in 2018. No data are available on system operations and optimization although wells were added in 1992. Further detailed hydrogeologic evaluations/modeling on the mass removal have not been conducted since that time.

Empirically, the maximum concentrations of TCE in the OOU plumes have generally decreased by an order of magnitude, but the overall geometry and maximal extent has remained relatively stable during the remediation. Initially the portion of the TCE plume exceeding 1,000 µg/L in the A, B1, and B2 aquifer zones extended from the Signetics Site beneath Kings Academy High School and to near or past Ahwanee Avenue. The B3 aquifer zone TCE plume initially exhibited maximum concentrations greater than 1,000 µg/L beneath the Kings Academy High School and extend slightly past Duane Avenue. These areas of maximal concentrations were mitigated by 2005; however, concentrations of up to 1,700 µg/L of TCE in the B1 aquifer zone and up to 7,400 µg/L TCE in the B2 aquifer zone are current detected in wells along the southern boundary of the OOU. The extent of the plume exceeding drinking water standards still extends beyond Ahwanee Avenue for the A, B1, and B2 aquifer zones.

The attached Figure 5 shows TCE concentration graphs for the nine reported A aquifer zone extraction wells grouped by extraction cluster. Evident on the graphs is the fact that TCE in OOU groundwater was relatively rapidly reduced to below 1,000 µg/L in each well cluster by the end of 1993. This is likely a result of the flushing action of the system on the highly-impacted preferred flow paths. The relatively stable TCE concentration exhibited in most wells after 1994 suggest the source of this residual TCE was either desorption from low permeability zones adjacent to the high permeable pathways or flow from ongoing sources not captured by the extraction system. Note, the use of extraction wells to evaluate TCE conditions likely result in a bias low as a result of dilution and an enhanced diffusion of sorbed contaminants.

The 100 µg/L TCE isoconcentration contour is a significant delimiter with regard to exposure to vapors phase TCE. The area that exhibits impact in the A and B1 aquifer zones above this delimiter exceeds the threshold EPA has considering as the highest priority for investigations related to the ongoing vapor intrusion issues. Historically, the reported 100 µg/L A aquifer zone TCE plume extended from beneath the Kings Academy High School through Duane Avenue to just past Alvarado Avenue. Curiously in 2018 (Figure 1), the reported 100 µg/L TCE contour was drastically reduced to include only a portion of the area beneath Kings Academy High School and a 100-foot diameter area about one extraction well along Alvarado Avenue that contained 110 µg/L TCE.

There are several areas where groundwater monitoring data is very sparse both in terms of performance monitoring and site characterization. There is only one A aquifer zone well

monitored (COM01A) between Duane and Alvarado Avenues (a distance of almost 1,500 feet) that characterized the TCE plume beneath nearly 100 residences and multiple schools. The elevated TCE plume does not appear to extent appreciable north of Alvarado Avenue; however, monitoring well COM41A along Ahwanee Avenue (Figure 5) exhibits increasing TCE concentration from not detected prior to 2002 to 34 µg/L in 2018 indicating that a slug of higher concentration groundwater is migrating from an upgradient location.

Like the A aquifer zone, the B1 aquifer zone TCE plume 100 µg/L isoconcentration contour historically extended from beneath Kings Academy High School past Duane, Carmel, and Alvarado Avenues. The current B1 plume map (Figure 2) indicate the 100 µg/L groundwater isoconcentration contours are isolated small circles about extraction wells along these three extraction clusters with maximum concentrations of 330 µg/L (Duane Avenue), 270 µg/L (Carmel Avenue), and 110 µg/L (Alvarado Avenue). Reductions in TCE concentrations in these B1 aquifer zone extraction wells are presented in Figure 6. As with the A aquifer zone extraction wells, B1 extraction wells show a fairly dramatic initial decrease in TCE concentrations that were reduced to less than 1,000 µg/L in the early 1990's. reduction in TCE since the late 1990's appear to approach asymptotic.

Historical data indicates that the highest concentrations of TCE are in the B2 aquifer zone, and concentrations of TCE in the B2 aquifer zone appear to be decreasing at a much lower rate than observed for similar wells in the A and B1 zone. Figure 8 shows changes in TCE concentration with time for the B2 zone extraction wells. Reductions in TCE to below 1,000 µg/L did not occur in all wells until the mid 1990's after which they appear to reach asymptotic conditions. The current B2 TCE plume (Figure 3) greater than 100 µg/L is similar to its historical extent; from beneath the Kings Academy High School to Ahwanee Avenue. Comparison of 2008 data to 2018 data indicates that the maximum TCE concentration along Duane Avenue decreased from 640 µg/L to 320 µg/L, but remained stable along Carmel Avenue from 300 µg/L to 310 µg/L. Concentrations along the more downgradient extraction clusters along Alvarado and Ahwanee Avenues may have decreased slightly or remained relatively stable; 250 µg/L to 230 µg/L, and 93 µg/L to 77 µg/L, respectively. These changes reflect a weakening source term and capture of the most contaminated portions in the upgradient portions of the plume near the source, however the gradual change in the downgradient portions of the plume suggests an ongoing source upgradient of these wells.

Impact to the B3 aquifer zone by the TCE release has historically been restricted to beneath Kings Academy High School, around Duane Avenue and south, and only two extraction wells along Duane Avenue are addressing this plume. Currently, the 100µg/L isoconcentration contour is defined by three wells ranging from 130 to 410 µg/L (Figure 4). The 100 µg/L isocontration contour occupies an area beneath the northeastern portion of the school. As

observed in other aquifer zones, TCE reductions were initially fairly rapid and have slowed considerably with subsequent operation (Figure 8).

As evidenced by the TCE graphs with time for the four aquifer zones the reductions in TCE concentrations have slowed. The 1991 ROD estimated a 36 year timeframe to achieve the regulatory cleanup level of 5 µg/L. Projections for the time to achieve cleanup for the A, B1 and B2 aquifer zones based upon current extraction operations are presented in Figure 9 using an exponential trend line based upon reported data. For the A aquifer zone two wells were selected; one along Duane Avenue and one along Alvarado Avenue to characterize the general A aquifer plume. Projections to attain cleanup along both Duane and Alvarado Avenues indicate a timeframe of around 2060, significantly longer than that estimated in the ROD.

Similar projections are made for the B1 and B2 aquifer zones (Figure 9). Using the extraction wells at Carmel Avenue to characterize these two plumes, the estimated timeframe to achieve cleanup in the B1 aquifer zone is about 2070 and that for the B2 aquifer zone is about 2085. Both are significantly longer than that estimated in the ROD.

AMD 915 DeGuigne Drive

Although the AMD Site 915 is not a formal component of Triple Site, corrective action at this site influences groundwater in the OOU. AMD operated the site as a semiconductor facility from 1974 to 2003 when Spansion LLC acquired the property for manufacture of memory devices that was terminated in 2009. Soil impacted by chlorinated ethenes was addressed in the early 1980's by excavation of 5,500 cubic yards. The existing facilities were demolished in 2016 and redeveloped as residential began. The residential units were constructed with vapor intrusion mitigation.

A groundwater and treatment system was installed and began operations in 1982 with four wells and four building sumps that was augmented in 1984 by two additional wells. A 1991 ROD formalized the extraction system and additional extraction wells and sumps were installed to address primarily TCE in the A, B1, and B2 aquifer zones and capture offsite migration of contaminants. Property transfer and redevelopment for residential use required decommissioning of the existing system and a new scaled-down extraction and treatment system was installed and began operations in 2016. As of 2017, 1,103 million gallons of groundwater were extracted and treated that contained 5,838 pounds of VOCs. The new system treated 9.6 million gallons of groundwater in 2017 that contained 7.3 pounds of VOCs. TCE concentrations in extraction wells ranged from 0.7 µg/L to 72 µg/L in 2017. Migration of contaminants from upgradient sources in inhibiting restoration of groundwater. Operation of the AMD system effects groundwater flow in the eastern border of the OOU: however, the

new scaled-down system appears to influence OOU groundwater flow much less than the previous system.

Suggestions for Improvement of OOU Corrective Action

The effectiveness of the OOU groundwater extraction and treatment system has decreased. The following suggestions are based upon the current understanding of OOU conditions. Additional information may refine these suggestions.

- A data gap investigation should be conducted to augment the current plume configuration, especially between Duane and Alvarado Avenues where there is considerable uncertainty in the configuration of the 100 µg/L TCE isoconcentration contour in both the A and B1 aquifer zones. This investigation is needed to quantify the potential risk of exposure to TCE at nearly 100 residences and multiple schools.
- A data gap investigation should be conducted to augment the current plume configuration in the downgradient area of the Plume between Alvarado and Ahwanee Avenues where there is uncertainty in the plume geometry and flow pathways that are resulting in an increasing trend at the plume leading edges.
- Acquire additional hydrogeologic and stratigraphic data to update the Conceptual Site with specific attention to preferred flow pathways and fill data gaps between extraction well clusters. Recommend high resolution site characterization methods.
- Conduct groundwater modeling by applying new hydrogeologic data with those acquired during the initial testing to refine extraction rates and determine flow paths to optimize extraction of TCE-impacted groundwater.
- Optimize the extraction system to enhance TCE reductions in the A and B1 aquifer zones and to reduce the timeframe to achieve cleanup in all aquifer zones.